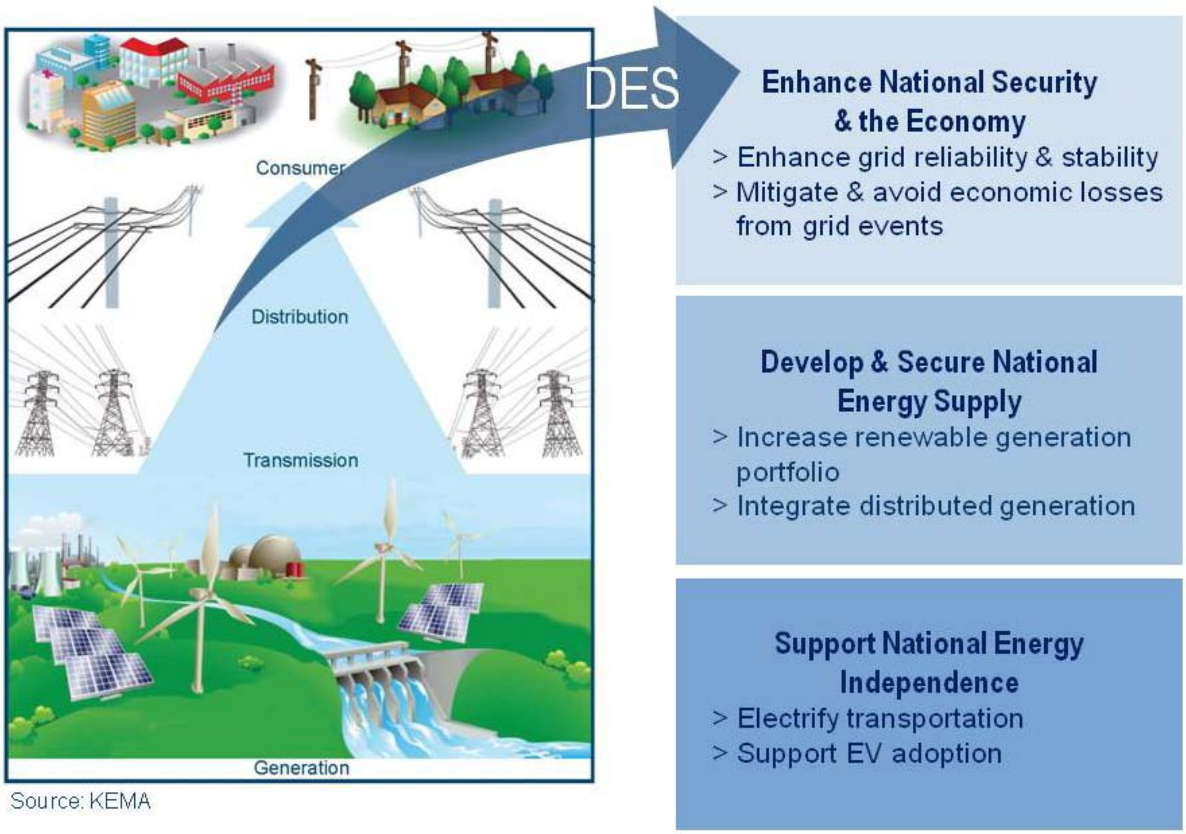
Distributed Energy Storage: Serving National Interests

Advancing Wide-Scale DES in the United States



Source: KEMA

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List of Exhibits:

Acronyms

AEP – American Electric Power
ARPA-E – Advanced Research Project Agency
BEEST – Batteries for Electrical Energy Storage in Transportation
BoP – balance of plant
CAES – compressed air energy storage
CES – community energy storage
C&I – commercial and industrial
DES – distributed energy storage
DisGen – distributed generation
DOD – Department of Defense
DOE – Department of Energy
FAT / SAT – factory acceptance testing / system acceptance testing
EIA – Energy Information agency
EV – electric vehicle
ESSP – Energy Storage Systems Program
GW – Gigawatt
GWh – Gigawatt hour
GRIDS – Grid-Scale Rampable Intermittent Dispatchable Storage
kW – kilowatt
kWh – kilowatt hour
LBNL – Lawrence Berkeley National Laboratory
MAIFI – momentary average interruption frequency index
MW – Megawatt
MWh – Megawatt hour
NAATBatt – National Alliance for Advanced Technology Batteries
OE – Office of Electricity Delivery and Energy
PCS – power conversion system
PV – photovoltaic
ORNL – Oak Ridge National Laboratory
RPS – renewable portfolio standards
SCADA – supervisory control and data acquisition
SAIDI / SAIFI – system average interruption duration index / system average interruption frequency index
T&D – transmission and distribution

Executive Summary

The confluence of four powerful trends underway across the nation's electric energy system is driving the need for a drastically different approach to managing our grid system in the twenty-first century: (1) the rapid penetration of intermittent renewable resources, including distributed wind and solar photovoltaics (PV), (2) the expected proliferation of electric vehicles (EVs), (3) the recent and continued advances in power electronics such as DC/AC inverters and smart batteries, and (4) a large-scale deployment of a sensing, control, and two-way communication smart grid infrastructure.

Together these trends create both new levels of risk to electric grid reliability, stability, and security as well as a tremendous opportunity—an interconnected system of millions of active endpoints introducing rapid, large, and random fluctuations in power supply and demand and an increased capability to coordinate and optimize these new control points. Grid-connected distributed energy technologies such as distributed generation, smart grids and microgrids, and EVs demand different degrees of freedom to manage and optimize the promise they bring.

The evolution of this envisioned grid-of-the-future is both supported and driven by numerous national energy policies, programs, and objectives. Distributed energy storage (DES) is a rapidly emerging and technology-neutral approach to accelerating the implementation of national energy policy and achieving the desired objectives – all while maintaining our electric grid system reliability, stability, and security. By employing the nation's innovations in advanced battery systems, DES is poised to help address the growing challenges our electric energy infrastructure will face as demand for electricity increases and as the distribution system must manage greater levels of distribution grid-connected and smart grid system-enabled technologies such as EVs, and renewable and distributed generation (DisGen).

Over the next decade, implementation of 150 GWh to 300 GWh of installed DES capacity could help support the nation's focus on modernizing our electric grid infrastructure—assets critical to supporting America's prosperity, security, and quality of life (see Exhibit 0-1). This range of DES installed capacity for 2012-2022 is based on data currently available in the public domain combined with assumptions on DES implementation and penetration. Additional information on the methodology used in this paper is provided in Section 1.2.

Exhibit 0-1: Potential DES Installed Capacity (GWh) & National Benefits

National Energy Policy Objective	National Interest	Role of DES in Serving the National Interest	Potential DES Capacity 2012 - 2022 (high & low scenarios)
1. Electric grid system reliability & stability	Protecting national grid security by reducing the vulnerability of local distribution systems to disruption from natural & malicious causes	• Supporting reliable grid operations through ancillary services including area regulation & voltage support • Helping reduce frequency & duration of grid events • Backup power source during grid events • Enabling T&D upgrade deferral – address challenges to urban & rural distribution system upgrades • Supporting consumer energy cost management such as time of use & demand charge management	**Avoiding Economic Losses from Grid Events** (Backup & Reliability Improvements) **150 GWh – 300 GWh**
2. Renewable distributed generation portfolio	Enabling achievement of state renewable energy goals by protecting the stability of the national grid	• Integrating renewable variable energy resources and distributed generation • Reduce output volatility, improve power quality • Firming intermittent renewable capacity • Matching supply availability to demand peak load • Backup for unexpected generation shortfall and managing ramp rates	**DisGen Integration** (Wind, Solar PV) **4 GWh – 10 GWh**
3. Mass consumer adoption of EVs	Supporting national energy independence by making EVs more affordable	• Ensuring grid flexibility to support EVs and charging infrastructure • Ensuring reliable, stable and available electricity supply for consumer charging needs • Supporting economies of scale in advanced battery production to reduce EV costs for consumers costs	**EV Charging & Grid Reliability** **0.2 GWh – 2 GWh**

DES systems have the ability to provide multiple services on the grid. These services broadly include electric supply capacity and energy time shift, ancillary services, transmission and distribution (T&D) system support, electric utility customer energy cost management, and renewable energy integration (see Exhibit 2-2 for a list of applications as defined by Sandia National Laboratories). The economic value of these services has been the subject of earlier studies. It is widely recognized that maximizing the value of DES systems will require that system operators be permitted to be compensated for all of the benefits to the grid that their DES systems provide.

This white paper, however, identifies additional national benefits from DES system deployment that earlier studies have not fully considered. These national benefits are:

- Enhancing the security of the national grid by reducing the vulnerability of local distribution systems to disruption from natural and malicious causes
- Enabling the achievement of state renewable energy goals by protecting the stability of the national grid, and
- Supporting national energy independence by making electric vehicles more affordable.

DES that leverages the advanced battery technologies being developed in the U.S. are of particular relevance to serving electric grid services of national interest and importance. Battery storage technologies are especially well-suited for DES applications—the technology is readily scalable, offering a high degree of flexibility and ease of location. This scalability is an important attribute. It enables DES placement at the "edge of the grid" where reliability has the greatest economic impact on the nation's electricity consumers and where variable renewable DisGen, EVs and EV charging infrastructure may require increased distribution system flexibility. This technology scalability can also enable DES application as an integrated component of smart grid and microgrid systems, helping to enhance and more fully achieve the envisioned benefits from smart grid investments.

This white paper argues that a key factor in encouraging DES system deployments in the U.S. will be developing a mechanism to compensate local electric utility customers paying for DES investments for the benefits such systems provide stakeholders outside the local rate-payer service territory. Sandia National Laboratories' 2010 guide on energy storage grid benefits and market potential assessment (SAND2010-0815) succinctly describes the combined utility customer / society-at-large energy storage benefit accrual consideration:

> *…it is important to consider some important storage-related benefits that accrue, in part or in whole, to electric utility customers as a group and/or to society at large.… In most cases, societal benefits are accompanied by an internalizable or partially internalizable benefit. Consider an example: A utility customer uses storage to reduce on-peak energy use. An internalizable benefit accrues to that customer in the form of reduced cost; however, other societal benefits may accrue to utility customers as a group and/or to society as a whole. For example, reduced peak demand could lead to reduced need for generation and transmission capacity, reduced air emissions, and a general improvement of businesses' cost competitiveness.*[i]

Regulatory, technology cost, cost of interconnection, and limited operational experience barriers currently hinder the wide-scale implementation of DES in the U.S. To overcome these barriers, this white paper makes six recommendations that can advance implementation of DES at the scale needed to support national energy policy objectives and to secure our nation's competitive position in the global DES market:

1) Establish a coordinated program of geographically diverse, small, and fast-to-implement demonstration projects that will help electric utilities to gain experience with DES systems, standardize their design and applications, and demonstrate their value proposition

2) Create a policy mechanism that will enable local electricity ratepayers to recover the "national interest value" of DES systems in which local ratepayers invest

3) Establish a coordinated nationwide approach to DES regulatory treatment that will permit DES system operators to be compensated for the full range of grid benefits they provide and include standardized interconnection

4) Continue to coordinate with existing energy storage standards development processes and help inform standardization of battery testing for grid applications

5) Continue to fund research, development, and deployment (RD&D) to reduce DES costs, including cell chemistry, materials and manufacturing, packaging, thermal components, and balance of plant-related costs such as power conversion, interconnection, communication, controls, and protection

6) Implement a national outreach campaign to educate stakeholders about the benefits of DES systems.

1. Background

The U.S. Department of Energy (DOE) asked the National Alliance for Advanced Technology Batteries (NAATBatt) to coordinate a white paper on distributed energy storage (DES) technology authored by a working group of industry stakeholders, including electric utilities with experience in DES, advanced battery manufacturers, and DES system integrators. The purpose of this white paper is to advise the DOE on its priorities for funding DES-related research and demonstration projects and on its approach to DES technology generally. The white paper also provides state regulators with a description of DES systems and their functions, and a framework for understanding the "national interest value" of DES systems in addition to the local system costs and benefits of such systems with which such regulators are more typically concerned.

The principal enabler of widespread DES system deployment is ensuring local electric utility customers paying for DES systems have the ability to capture the substantial, wider-scale DES application benefits provided to stakeholders beyond the local service territory of deployment. Providing utilities and their customers the ability to accrue DES benefits of "national interest value" – that is benefits that serve utility customers as a group and/or society as a whole – helps position DES systems as viable, economic options to utilities and their regulators.

DES systems offer a range of grid applications and a range of value streams, some local and some national in impact. Wide-scale implementation of DES can help achieve national energy policy objectives and benefit all Americans by helping to ensure a more secure electric grid system, by reducing the costs of vehicle electrification, and by supporting efforts to secure national energy independence. Recognizing those national benefits, assigning a value to them, and ensuring that those utilities and ratepayers who invest in DES systems are able to be paid for the national benefits they provide is the key to deploying this technology. By identifying and discussing the national benefits of DES systems, this white paper seeks to provide a resource that all participants and stakeholders in the nation's electric grid system can use to define, refine, and create specific programs, policies, and regulations that will encourage wide-scale implementation of DES.

1.1 Context of the DES Paper

On April 21, 2011, NAATBatt and the DOE hosted a one-day workshop, in Chicago, Illinois, on the challenges in utility deployment of DES systems. At the workshop representatives of electric utilities and advanced battery companies discussed and identified issues that regulated electric utilities would need to resolve to facilitate wide-scale deployment of DES systems—such as substation, residential and community energy storage systems—on the distribution portion of the grid.

The workshop was an interactive program in which all participants contributed their experience and expertise. Each participant was assigned to one of three roundtable working groups to discuss a particular category of issues and each working group reported its conclusions back to the full workshop session at the end of the day. These working group reports served as the foundation for this white paper.

This white paper seeks to lay the groundwork for a consistent policy approach to DES technology at the federal and state levels. The intent of this paper is to help maximize cross-industry education and understanding of key issues and to identify strategies by which DES systems can be advantageously and profitably deployed to the benefit of the nation as a whole.

1.2 Methodology

The DES white paper was written with the benefit of direct input from a NAATBatt-coordinated working group as well as drawing from key industry, government, and market reports currently available in the public domain. The NAATBatt working group members provided their perspectives based on decades of cumulative experience and insight in the energy storage and utility industry. These perspectives were gathered and aggregated through phone surveys of individual working group members conducted by KEMA Inc., and through full working group discussions.

There are numerous reports and studies existing in public domain that focus on the technical specifications, applications, and economics of deploying energy storage systems within individual service territories. This white paper is different in that it focuses on the national benefits of DES and the important role this technology can play in securing a cleaner, more secure, and more robust energy future for the entire country. In so doing, this white paper is designed to encourage a dialog among federal and state policy makers as to how best to support wide-spread deployment of DES systems. This white paper suggests a general range of the amount of DES needed in the U.S. over the next ten years to help support national energy policy objectives. The DES market size forecasts draw from data available in the public domain. Data sources and assumption made are cited in the white paper. In-depth market penetration modeling was beyond the scope of this white paper and is a subject of broader on-going industry discussion and activity.

1.3 About NAATBatt

NAATBatt is a not-for-profit trade association of foreign and domestic corporations, associations and research institutions focused on the manufacture of large format advanced batteries for use in transportation and grid-connected energy storage applications in the United States. Members include advanced battery and electrode manufacturers, materials suppliers, equipment vendors, service providers, and universities and national laboratories.

NAATBatt's core missions are to encourage U.S. leadership in advanced battery technology and to grow the North American market for products incorporating that technology. Energy storage will be a critical technology in the automobile industry and in the electricity grids of the future. The long term health of the U.S. economy, and tens of thousands of future U.S. jobs, depend in no small part on the ability of U.S. companies to at least remain competitive, if not to become leaders, in this critical technology.

1.3.1 NAATBatt Working Group

The working group assembled by NAATBatt for the DES white paper includes representatives from a cross-section of utilities, energy storage manufacturers, system integrators, automotive manufactures, and government entities from across the nation. The 13-member working group involved the active participation of the following organizations:

- **ABB** (www.abb.com)
- **American Electric Power (AEP)** (www.aep.com)
- **Altairnano** (www.altairnano.com)
- **Boston-Power, Inc.** (www.boston-power.com)
- **DTE Energy** (www.dteenergy)
- **Dow Chemical Company** (www.dow.com)
- **Dow Kokam** (www.dowkokam.com)
- **Duke Energy** (www.duke-energy.com)
- **EaglePicher Technologies, LLC** (www.eaglepicher.com)
- **General Motors Company** (www.gm.com)
- **International Battery** (www.internationalbattery.com)
- **Oak Ridge National Laboratory (ORNL)** (www.ornl.gov)
- **S&C Electric Company** (www.sandc.com)

NAATBatt retained energy and utility consulting, testing, and certification company, KEMA Inc. (www.kema.com) to help facilitate working group discussions and efforts related to this white paper and served as the primary technical writer.

2. Distributed Energy Storage

Energy storage as a concept is not new to our nation’s electric energy system. Energy storage technologies such as lead-acid batteries, pumped hydro storage systems, and compressed air energy storage (CAES) have been in use for many years to help match generally centralized electric supply with demand.

What is new today is the need to locate energy storage further out along the distribution system at substations and feeders and end-user premises. Our electricity system is rapidly evolving as national energy policy continues to focus on increasing levels of grid-connected technologies such as smart grid, intermittent renewable and distributed generation (DisGen), and electric vehicles (EVs). Where variability on the grid system had been attributed primarily to load dynamics, now generation itself is becoming more variable. This makes the grid system more unpredictable and makes managing the system for reliability, stability, and security more challenging. The complexity and distribution of variable generation and emerging new loads on the system, such as EVs, requires solutions that are located near distribution system assets. Distribution-based solutions help new grid-connected technologies work most effectively.

Energy storage, both centralized and distributed, is playing an increasingly important role in helping to balance our grid system and to ensure system reliability and stability. Our nation's electric generation portfolio will always include centralized resources along with increasing levels of intermittent or variable energy resources (VERs) such as wind and solar. As such, large-scale energy storage will continue to play an important role on the grid. As distributed energy resources are increasingly implemented on the system, DES's "option-rich" attributes in terms of scalability, location, and application will become increasingly valuable – even critical – to achieving national energy policy objectives and creating a modern and secure electric grid system.

2.1 Definition of DES

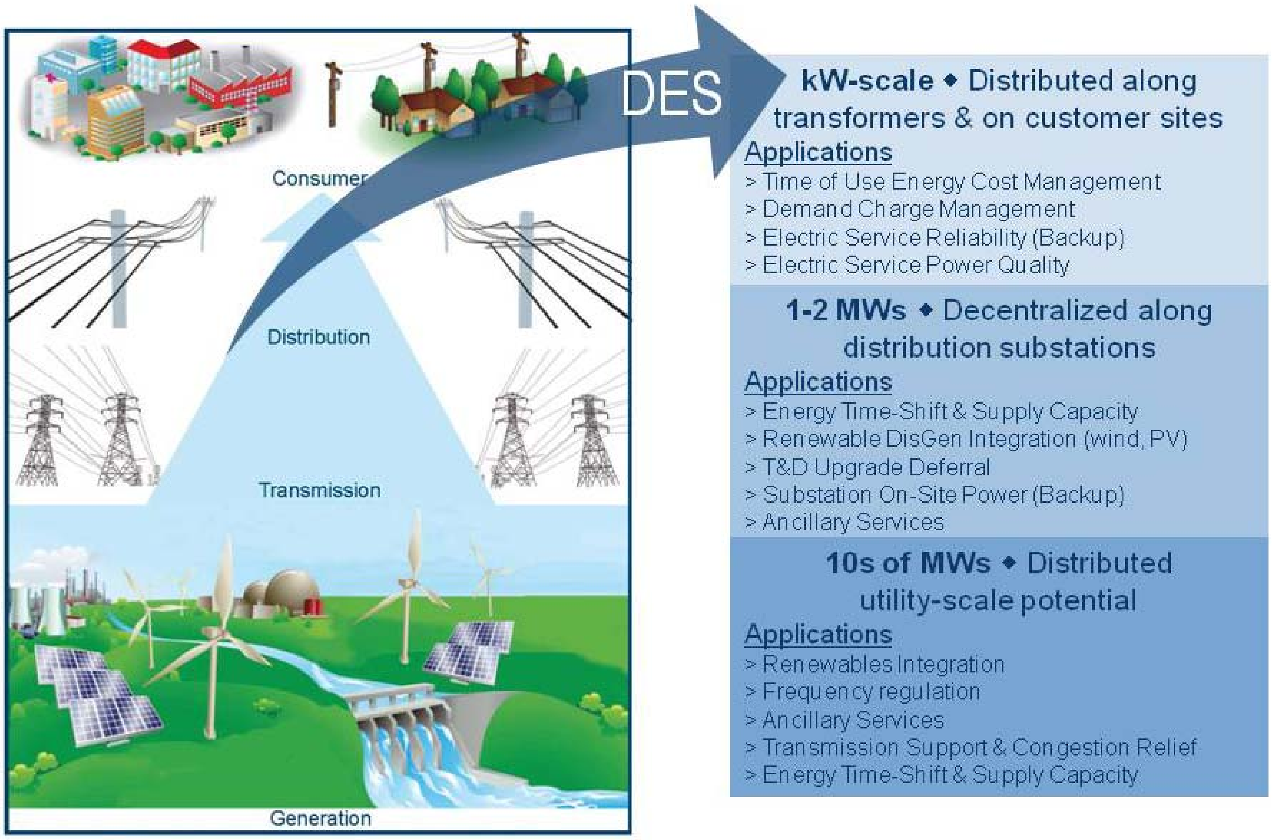
For purposes of this discussion, NAATBatt broadly defines DES as a group of typically smaller energy storage units sited on the distribution-side of the electric grid system—either at a distribution substation, along the system feeders, or at an electric utility customer premise. DES units are usually two (2) megawatts (MW) or less in size. However, DES units can also potentially be scaled in the tens-of-MWs range in certain grid applications. A new and emerging DES concept of community energy storage (CES) shows promise for wide-spread deployment. CES is a kilowatt (kW)-scale energy storage unit connected to secondary transformers along feeders serving groups of houses or small commercial buildings. Exhibit 2-1 offers a visualization of the different scales and locations of grid-connected energy storage technologies.

Because DES is distributed in nature, it can address multiple grid challenges at the same time. In single centralized storage units one function can tie up the full capacity of the device—even if that function requires only a fraction of the device's full capacity. With a DES system of equivalent capacity, different storage units can offer different functions depending on their location and on the needs of the local distribution system.

By providing different functions at specific locations according to location-specific requirements, DES is able to provide multiple benefit streams to different end-users—from electric utility customers, to utilities, to system operators. In combination, the multiple and varied benefits of

DES can be extremely effective in supporting overall grid reliability and stability—benefiting all Americans in ways that support national energy policy objectives, including wide-scale adoption of EVs, increased levels of renewable and distributed generation, and job growth and a strengthened economy.

Exhibit 2-1: Different Scales & Locations of Distribution Grid-Connected DES



Source: KEMA

2.2 DES Performance Requirements & Specifications

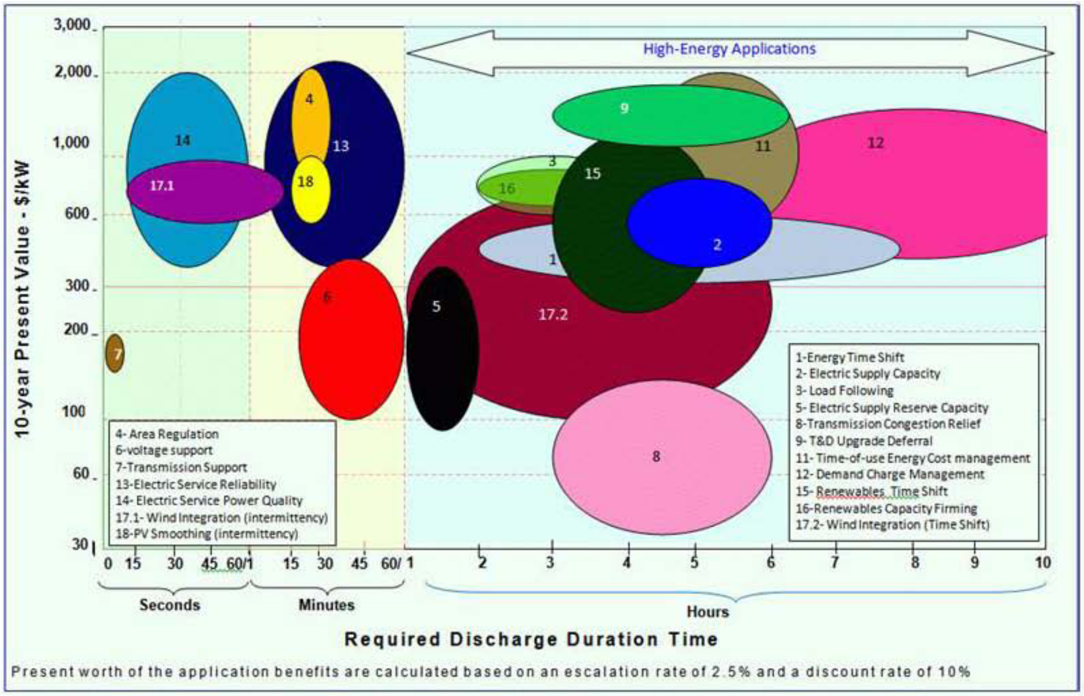
As summarized in Exhibits 2-2 through 2-4 on the following pages, DES performance requirements can vary depending on system location, size and application needs. Performance requirements can also vary according to the primary end-user application a DES is designed to meet. Specific system needs center around cycle life, energy density, response time, rate of charge and discharge, and efficiency. DES unit performance characteristics have a direct impact on the overall system economics and on the realizable benefits.

From a benefits perspective, DES system performance may be optimized by addressing multiple, compatible applications to increase the technology benefit or value to the end-user. Additional applications must have technical compatibility as well as business compatibility. Technical compatibility means the same energy storage capacity can be shared by different applications. Business compatibility means the owner is capable of realizing a financial value for the net economic and other benefits of a given energy storage asset for multiple applications. Placing a dollar figure on energy storage benefits is a current subject of often intense debate among energy storage industry experts and stakeholders. While subject to further evaluation, Exhibits 2-2 and 2-3 offer a summary of energy storage application benefit ranges as defined in Sandia National Laboratories report, "Energy Storage Market Potential Assessment" (SAND2010-0815[ii]). The intent is to provide a general point of reference on possible value stream to end-users.

Exhibit 2-2: Energy Storage Grid Applications & System Requirements

Applications & Requirements	Group 1	Group 2	Group 3	Group 4
Storage Type	High-energy	High-power	High-energy	High-power
Discharge Duration	Hours	Minutes	Hours	Seconds
Frequency of Usage	Frequent	Frequent	Occasional	Occasional
Applications (# correspond to those used in SAND2010-0815)	1. Energy Time Shift 2. Electric Supply Capacity 3. Load Following 11. Time-of-use Energy Cost Management 12. Demand Charge Management 15. Renewables Time-shift 16. Renewables Capacity Firming 17.2. Wind Integration (time shift)	4. Area Regulation 6. Voltage Support 17.1. Wind Integration (intermittency) 18. PV Smoothing	5. Electric Supply Reserve Capacity 8. Transmission Congestion Relief 9. T&D Upgrade Deferral 10. Substation on-site Power (DC backup) 13. Electric Service Reliability (Backup)	7. Transmission Support 14. Electric Service Power Quality

Exhibit 2-3: Energy Storage Grid Applications Grouped by Power & Energy Densities



Source: KEMA

Exhibit 2-4: General DES System Performance Specification by End-User

End-User	Key Parameter	Value
Residential	Power (active & reactive)	up to 100kVA
	Energy	up to 2 hours of discharge at rated power
	Voltage	120V/240V, single phase
Commercial & Light Industrial	Power (active & reactive)	Up to 500 kVA
	Energy	up to 2 hours of discharge at rated power
	Voltage	480V, three phase
Renewable	Power (active & reactive)	Application-specific
	Energy	Application-specific
	Voltage	Application-specific
Utility & System Operators	Power (active & reactive)	Larger than 1MVA
	Energy	Application-specific
	Voltage	Use Step-up transformers

A DES system can consist of a number of different types of energy storage devices. Typically, an interconnected DES system is comprised of a distributed fleet of advanced battery technologies, each providing at least 15 kVA of active and reactive power and 25-75 kWh of energy at 240/120V AC. The DES fleet also requires a central dispatch control and communications to optimize the system operations and benefits.

The DES system battery may be physically identical for both end-use electricity customer and for utility applications. The main difference between the end-user and utility application systems is in the control logic, interconnection voltage, communications protocols, and software. For example, an end-user renewable application battery system needs to be operationally optimized for applications of high value to customers and include a control interface that meets the facility energy management system. Likewise, a utility renewable application battery needs to be optimized for the utility operations with a SCADA interface to allow central dispatch control. There are numerous economic studies in the public domain that put dollar figures on cost targets by energy storage technology type. In general, DES technology costs in dollars per kilowatt hour ($/kWh) need to realize a reduction of 50 to 75 percent relative to today’s initial capital cost. Exhibit 2-3 above summarizes the present value of these costs ranges in $/kWh. In addition to technology costs, additional costs such as packaging, inverters, interconnection, and thermal management also need to be reduced.

2.3 DES System Design

DES system design must address the unique operation, maintenance, safety, and aesthetics considerations associated with locating storage units closer to the end-use utility customer. From a cost and deployment perspective, there has been increasing interest among end-users of energy storage in smaller and more “plug-and-play” packaging. Plug-and-play packaging can help facilitate wide-scale deployment of DES by reducing installation cost for the end-user. This plug-and-play packaging does not necessarily require a change in the battery design, but rather it is a move to reduce the total installed cost of almost any energy storage system. General characteristics of a plug-and-play packaging include:

- Pre-assembled in a container that can be shipped as one piece requiring minimal assembly on site
- Standardized sizes with matching power conversion system (PCS), whether it is inside the battery container or separate.

- Connecting the plug-and-play units at the AC side to make larger units. Having multiple standardized PCS units connected at the AC side is often less expensive than connecting battery units at the DC side and designing a custom PCS unit that would be different size for different projects. Custom PCS would significantly increase other non-recurring engineering costs and increases the risk of control mis-function that would again contribute to the installation time and cost.

3. DES Benefits of National Interest

Governments the world-over pursue policies and programs designed to secure, protect, and enhance infrastructure assets deemed critical to their nation's prosperity and security. In the United States, the definition of "critical infrastructure" has evolved throughout the decades. However, that definition has consistently included electric energy production, transmission, and distribution services and facilities as critical infrastructure and key assets.[iii]

The current administration continues in the tradition of its predecessors to recognize the importance of the electricity grid to the U.S. economy. In addition, it has recognized the growing importance of electrical power to U.S. energy security and the increasingly central role that the electricity grid will play in U.S. energy policy going forward. For example, in its March 2011 "Blueprint for a Secure Energy Future,"[iv] the Obama Administration outlined three specific goals, each of which can be furthered by DES technology:

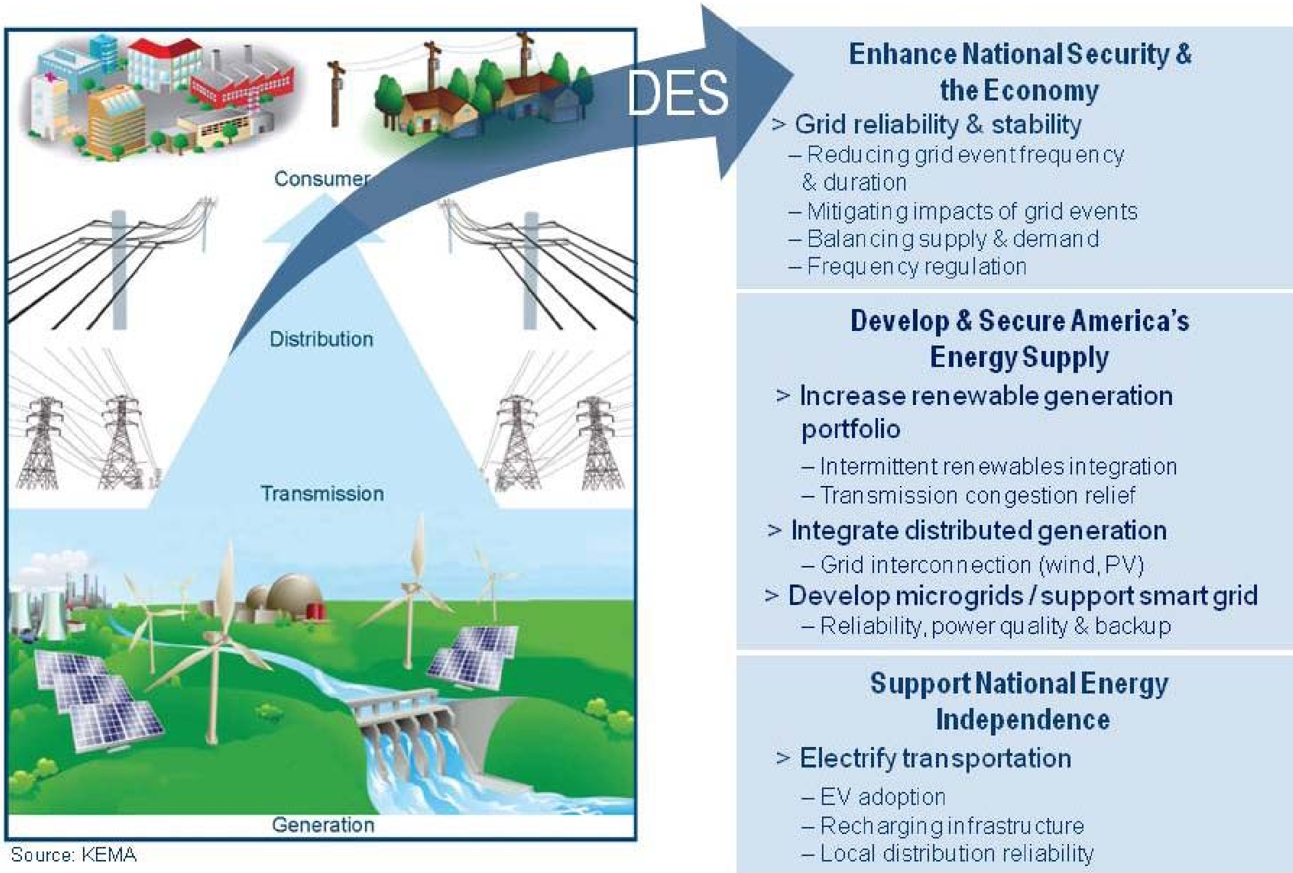
- National energy independence through the electrification of transportation and wide-scale adoption of EVs

- Enhanced national security and economic growth through a reliable and stable electric transmission and distribution system and affordable electricity prices

- National energy supply development and security through a diversified electric generation portfolio that includes a greater proportion of intermittent renewable generation, including wind and solar.

Exhibit 3-1 illustrates how each of the three national goals outlined above will be achieved by use of electric power on the grid. The following sections discuss the important role that DES can play in achieving these goals and in addressing the challenges that achieving them will place on existing electricity transmission and distribution systems.

Exhibit 3-1: National Policy Objectives & the Electric Grid System



Source: KEMA

3.1 Grid Infrastructure: Reliability, the Economy & Renewable Energy

Achieving U.S. energy policy objectives will require maintaining a reliable, stable, and secure grid system. The nation's existing grid system faces a number of challenges to reliability, including aging assets, a graying workforce, and evolving electric energy load profiles. High penetration levels of renewable distributed generation (DisGen) introduce a need for greater grid system flexibility to effectively and efficiently integrate variable, intermittent energy sources such as wind and solar PV. Mass consumer adoption of EVs likewise can compound the need for a greater level of grid system flexibility. DES is poised to help optimize system integration of DisGen and EVs, while helping to support reliable and stable grid system management and operations.

3.1.1 DES Role in Mitigating Economic Impact of Grid Events

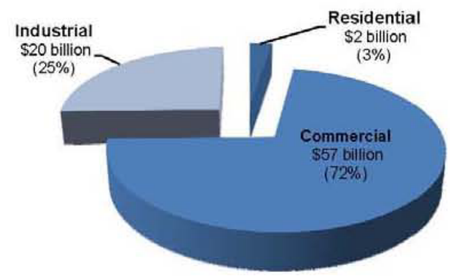
According to a 2004 Lawrence Berkeley National Laboratory (LBNL) study, “Understanding the Cost of Power Interruptions to U.S. Electricity Consumers” (LBNL-55718), sustained and momentary interruptions on the grid system cost the national economy $80 billion annually. Further sensitivity analysis suggests this cost can range anywhere from $30 billion to $130 billion annually.[v] The commercial and industrial (C&I) sectors, the engine of our national economy, bear 98 percent of these costs.

Distribution systems face various location-dependent technical and environmental challenges that contribute to the type, frequency, and duration of grid events. DES offers backup and reliability improvement benefits that can help avoid economic losses from grid events. However, at present-day pricing the reliability benefit revenue stream does not currently exist at the utility level or the industry level to install DES at all of the locations that could benefit. While DES technology itself is a viable option, it is the economics of installing DES for grid reliability benefits needs to be addressed.

As summarized in Exhibit 3-2, the LBNL study found that 67 percent of total economic losses are due to the frequency of short-term, momentary interruptions of service of five minutes or less. With several hours of discharge capacity DES can help reduce customer vulnerability to grid events, by helping to:

- Provide a backup source of electricity during short-duration events
- Provide ride-through service during sustained interruptions greater than five minutes and upward of a few hours in duration
- Avoid customer economic losses due to power or power quality failure.

Exhibit 3-2: Economic Impact of Grid Events by Source, Frequency & Duration

	Source	Frequency (# interruptions per customer / year)	Duration (per customer / year)	Economic Loss ($ billion)	Total Loss by Customer Class
Momentary Interruptions	**Transient Fault** • Temporary fault on distribution feeder	4.3 MIAFI (mean)	Seconds	**$52 b** (67% of total losses)	
	Brownout (sag) • Drop in voltage		> 1-5 minutes		
Sustained Interruptions	**Blackout** • Power generation station tripping • Damage to transmission, substations, or distribution system (short circuits, overloading)	1.2 SAIDI (mean)	106 minutes (1.8 hours) SAIDI (mean)	**$26 b** (33% of total losses)	

Data source: Lawrence Berkeley National Laboratory (LBNL-55718)

DES located on distribution feeders can help significantly improve reliability at the distribution level. A reduction in system average interruption duration index (SAIDI) from 60 minutes a year to about 30 minutes a year may be feasible. As shown in Exhibit 3-3, DES penetration with an installed capacity to help address 10-20 percent of the total underserved energy identified in the LNBL report—150 GWh to 300 GWh of DES as backup and/or grid reliability improvement systems—could help avoid between $110 million to $580 million in annual national economic losses from grid events.

Exhibit 3-3: Annual U.S. Economic Losses Avoided by Wide-Scale DES Deployment (High & Low Scenarios)

DES MWh & Potential U.S. Economic Losses Avoided (High & Low Scenarios)									
	Total Unserved Energy (MWh) Assumption*		DES Penetration Scenarios	Total DES Penetration (MWh)		Energy Storage Benefit Assumption**	Total Economic Losses Avoided ($ million, rounded)		
	Momentary Grid Events (5 mins, 4/year)	Sustained Grid Events (1 hr, 1/year)	Percent	Momentary Grid Events	Sustained Grid Events	$/kWh	Momentary Grid Events	Sustained Grid Events	Total Grid Events
High	**1,515,000**	1,450,000	20%	303,000	290,000	$ 980	$ 300	$ 280	$ 580
Low	**1,515,000**	1,450,000	10%	151,500	145,000	$ 360	$ 60	$ 50	$ 110

* Data sources: Lawrence Berkeley National Laboratory (LBNL-55718, LBNL-2132e)
** SAND2010-0815 energy storage reliability benefit

In addition, DES, when fully deployed and integrated, could potentially carry an entire distribution substation load for several hours – helping to improve service reliability. Only those outages that require numerous hours to resolve when significant physical damage occurs would exceed the storage duration. Typical outages that require a few hours to fix should not result in any loss of service.

Residential electricity customers will also be major beneficiaries of DES systems and their impact on grid reliability. Although the residential sector accounts for only two percent of measured losses from service interruptions, the impact of such disruptions on quality of life, satisfaction with utility and government service, and unreimbursed losses of perishable consumer goods are generally not accounted for in the monetary calculation of national losses from electricity system disruptions. Yet these losses can have profound impacts on governments and electrical utilities, manifesting themselves, among other ways, in forced resignations of experience managers and the disruptive reordering of political and public policy priorities. By bolstering the reliability of distribution systems serving residential customers, DES systems benefit the electricity system in ways not easily measured in monetary terms.

The challenge to realizing this national economic benefit of DES is cost. Current DES installed costs are upward of $1,900/kilowatt hours (kWh). This cost is well above Sandia's projected energy storage reliability benefit of $360-$980/kWh. As such, DES reliability applications in the U.S. currently are limited to niche markets with higher returns on investment. However, DES can offer additional benefit in terms of allowing for the deferral of installation/upgrade investments in T&D lines, substations, and equipment and components needed to support service reliability. Sandia has projected the T&D deferral benefit as ranging between $480-$1,080/kWh. The DES T&D application can also help address issues presented by the difficulty in siting T&D infrastructure. The previously cited LBNL study on the costs of U.S. power interruptions notes that energy storage may offer a "superior solution for reliability enhancement if conventional utility options to improve reliability are limited or constrained and/or for locations where noise, air emissions, zoning, or fuel-related issues limit use of generation-based solutions. Furthermore, unlike generation-based solutions most storage (system) types respond instantaneously to power quality events and to outages."[vi]

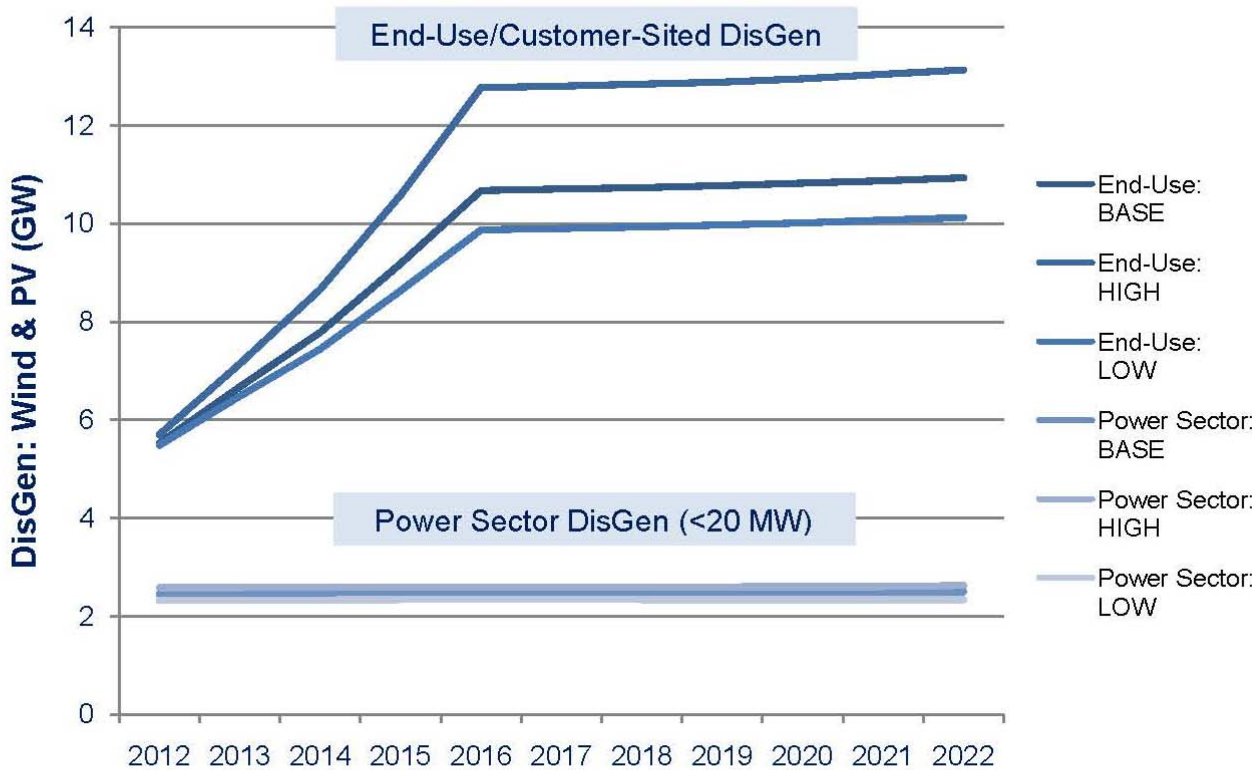
3.1.2 DES Role in Enabling Renewable Distributed Generation

Electricity generated by intermittent renewable resources is destined to become a growing part of our national electricity supply. As of May 2011, 29 states have enacted mandatory renewable portfolio standards (RPS), requiring that, as of certain specified future dates, minimum percentages of electricity consumed in the state come from renewable sources. An additional nine (9) states and three (3) power authorities have enacted voluntary RPS targets.[vii] The large majority of this renewable energy will come from intermittent wind and solar resources. Because these resources are variable, generating electricity when the wind blows or when the sun shines rather than when grid operators want to generate electricity, maintaining the stability of the grid while integrating this growing quantity of variable renewable energy onto it will be one of the great power engineering challenges of the early 21st Century.

Of equal, if sometimes overlooked, implication to the stability of the grid is the growing percentage of intermittent renewable energy that will come from distributed generation (DisGen) rather than from centralized generation. A significant and growing amount of the renewable energy used on the grid will come from DisGen sources, such as rooftop solar and small wind and community wind generators. The localized addition of additional variable energy resources (VERs) to the grid adds a complexity to grid management, the ramifications of which extend far beyond the individual service territories where that DisGen is added. As of May 2011, 16 states have set-asides written into their RPS statutes requiring certain minimum amounts of DisGen.[viii]

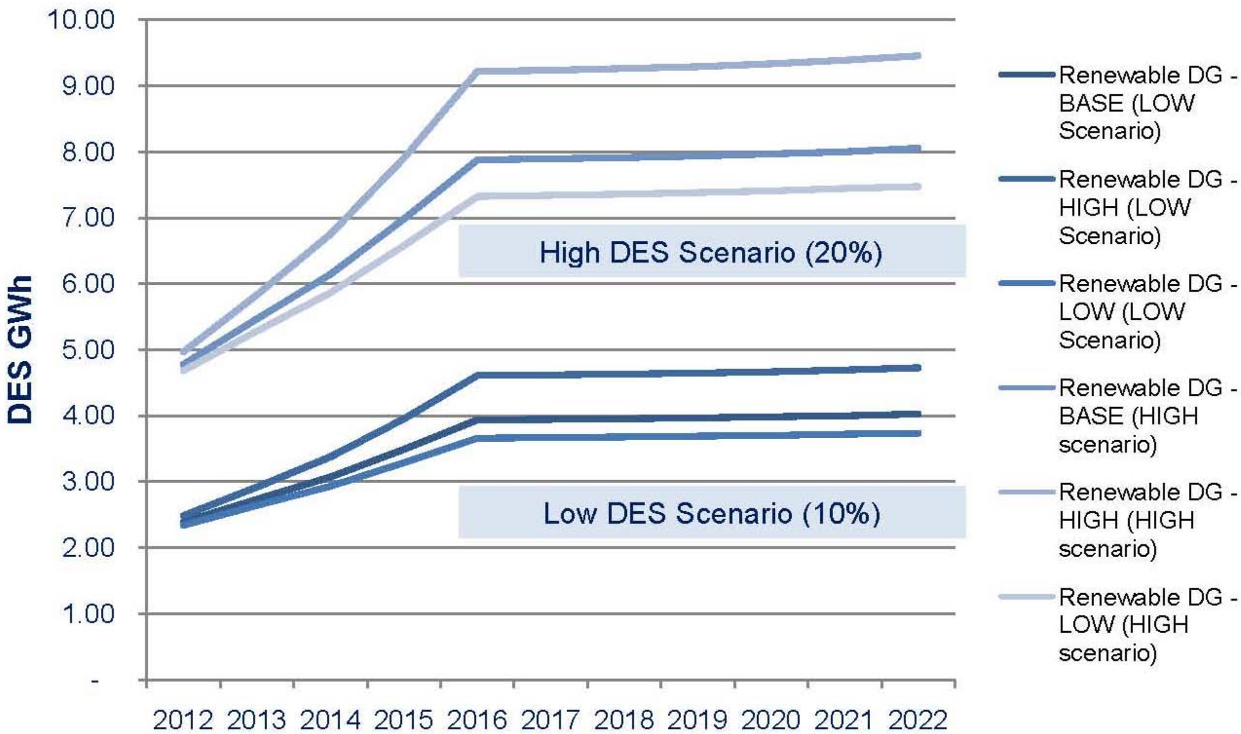
Over the next decade, end-user intermittent renewable DisGen (wind and solar PV) is projected to double.[ix] By 2022 the U.S. is forecasted to have between 13 GW and 16 GW of renewable DisGen connected to the grid system (see Exhibit 3-4). Of this amount of DisGen, more than 80 percent will be end-user/customer-sited renewable, predominantly solar PV. The remaining amount will be grid-connected power sector renewables, generally wind projects of less than 20 MW. As shown in Exhibit 3-5, the implementation of 4 GWh to 10 GWh of DES over the next ten years can help integrate the growing amounts of variable renewable DisGen.

Exhibit 3-4: U.S. Distributed Generation (GW) – Wind & Solar PV: 2012-2022 (Base, High & Low Scenarios)[x]



Data source: U.S. EIA

Exhibit 3-5: DES Needed to Address "Buffering" Challenges of U.S. Distributed Generation – Wind & Solar PV: 2012-2022 (High & Low Scenarios)[1]



Data source: U.S. EIA

Transmission and distribution systems have been built on the assumption that load varies slowly in the aggregate and that generation sources for the most part can be scheduled when needed. Large percentages of wind and solar energy can cause sudden variability in supply versus load, resulting in system regulation problems and voltage fluctuations. Interconnecting renewable DisGen with the distribution system introduces additional challenges to grid reliability and stability. Protecting the stability and security of the national power grid against instability that may arise on account of local integration of DisGen and other renewable energy is of critical national importance.

[1]Based on U.S. EIA renewable energy generation projections for electric power sector and end-use generators (solar PV, wind); includes 100% end-user and 5% electric power sector renewable are distributed (<20 MW); assumes 2kWh per kW renewable. Note that 1 kWh DES needed per kW renewable for smoothing application and 2 kWh DES needed per kW renewable for firming & shifting applications.

DES is uniquely positioned as a technology to help the national power grid face the challenges posed by widespread integration of intermittent renewable energy and DisGen. In particular, DES can help address the three "buffering" challenges that variable energy resources introduce on the distribution grid:

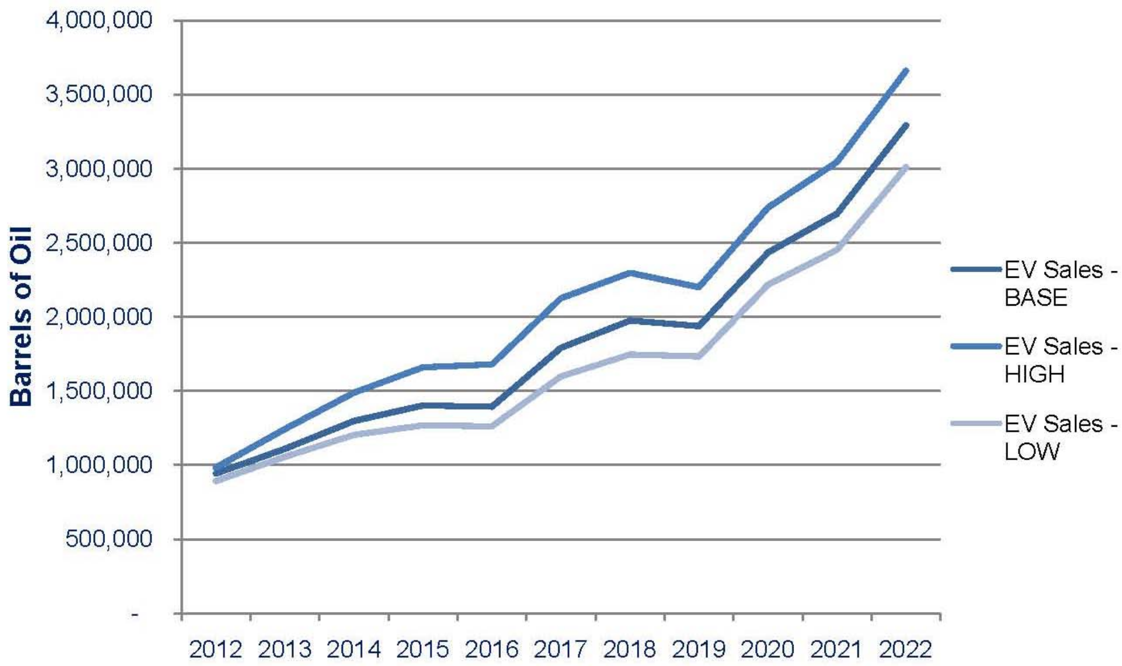
- Smoothing (or ramp control) – a storage function that helps reduce the adverse impacts of a very fast change in renewables generation level or output
- Capacity firming – a storage function to help maintain the power output at a committed (firm) level for a reasonable time
- Time-shifting – a storage function to match generally off-peak demand renewable energy supply with on-peak demand; the device can store energy during this period and discharge back to the grid during peak periods.

DES also can provide frequency regulation applications needed to address the grid reliability and stability issues associated with both DisGen and centrally located renewable energy generators. For example, each 100 MW of wind energy requires 3 MW to 5 MW of additional frequency regulation. FERC has recognized the critical role energy storage plays in balancing supply and demand for system reliability as a frequency regulation resource. In October 2011 FERC issued a final rule (Final Order Number 755) "Frequency Regulation Compensation in the Organized Wholesale Power Markets" that requires independent system operators / regional transmission organizations (ISOs/RTOs) to compensate frequency regulation resources—including energy storage—based on the actual service provided. The rule ensures just and reasonable capacity payments based on the marginal unit's opportunity costs and a payment for performance that reflects the quantity of frequency regulation service provided. Studies have shown that fast responding energy storage for frequency regulation reduces the amount of needed regulation, greatly improving energy efficiency and reducing carbon emissions. There is no compensation for the reduced carbon emissions.

3.2 Electric Vehicles: Supporting Energy Independence

According to U.S. Energy Information Agency (EIA) data, the U.S. imports about 11.8 million barrels of oil a day, accounting for about half of total U.S. demand.[xi] Over 70 percent of this imported oil is used for transportation. Within the transportation sector, about 60 percent of petroleum is used for light-vehicles and almost 100 percent of the U.S. light-vehicle fleet is dependent upon petroleum-based fuels.[xii] Electrification of transportation through the wide-scale consumer adoption of EVs offers an opportunity to support the nation's energy independence through "fueling" vehicles via our nation's electric grid system. Consumer EV adoption—electric and plug-in hybrid (PHEV) cars and light trucks—offer a potential to offset oil imports by a cumulative 18-23 million barrels over the next decade (see Exhibit 3-6 below).

Exhibit 3-6: Annual Oil Imports Offset by U.S. EV Adoption: 2012-2022 (Base, High & Low Adoption Scenarios)[2]



Data Source: U.S. EIA & EPA

Three barriers to wide-scale consumer acceptance of EV's need to be addressed: (1) overcoming consumer "range anxiety" through a readily accessible and reliable EV charging infrastructure, (2) making EVs more affordable, and (3) ensuring the electricity infrastructure has the flexibility to serve growing EV charging loads.

DES can help support the greater flexibility needed in the grid system to support increasing demand and/or shifts in demand for electricity for home/on-premise EV charging and for a national charging infrastructure. DES can also help enhance the "green" value of EVs facilitating the use of distributed renewable generation for EV charging. Finally, by increasing the volume of advanced battery production and by providing opportunities for secondary battery use, DES offers an avenue to help reduce the cost of advanced batteries and position EVs as a more affordable vehicle option for U.S. consumers.

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[2]Based on U.S. EIA EV & PHEV sales projections (cars, light trucks); assumes annual per internal combustion vehicle gasoline use of 520 gal for cars, 870 gal for light trucks (U.S. EPA data)

Because of DES is able to move or shift demand for electricity over time, DES systems can be an important tool for grid operators to smooth the integration of EVs onto the grid while maintaining and protecting grid reliability and stability. DES is a grid-connected technology option that can help support more effective charge management via electric service rates and/or direct load control. DES can also help increase capacity on the grid system, allowing for quick and localized expansion of grid capacity to satisfy charging needs. In addition, DES is an option for grid operators to utilize to defer upgrades to existing distribution assets which might, in the absence of DES, need to be upgraded in order to accommodate EVs.

As an efficient and effective means for enhancing grid flexibility needed to support EV charging, DES can help ensure that the nation's emerging EV charging and electric system reliability needs are met simultaneously. For example, the deployment of 0.8 GWh to 2 GWh of energy storage in the U.S. over the next decade (see Exhibit 3-10) could play an important role in providing the grid flexibility needed to support the 1.4 – 1.8 million EVs/PHEVs projected to be on the road by 2020.[xiii] The addition of wide-scale DES to our electric grid system can help support the national benefits afforded by the mass consumer adoption of EVs, including helping to support energy independence. This wide-scale implementation of DES can also help bring down the cost of advanced batteries, one of the significant cost components to address in making EV affordable for consumers (see Section 3.2.2).

3.2.1 DES, EV Integration & System Reliability

Two significant challenges to wide-scale EV adoption are (1) the lower vehicle range versus that of existing gas vehicles ("range anxiety"), and (2) the relative convenience of EV recharging, versus the five- to ten-minutes it takes to refill at a gas station. Both technical challenges can be addressed through the development and deployment of a robust charging infrastructure, one that includes both home- and public-based charging capabilities and that facilitates a range of charging time options. Exhibit 3-7 highlights the set of charging options—or "Levels"—currently available or in development—and their relative impact on the need for distribution grid flexibility.

Exhibit 3-7: EV Charging Level Options & Relative Grid Flexibility Needs

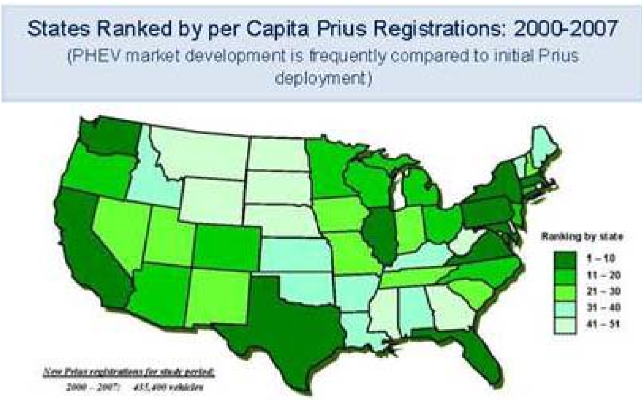
Charger Type [charging station standards status: Society of Automotive Engineers (SAE)]	Sample Service	Application	Charger Power	Charge Time (for a nearly discharged vehicle)	Potential Relative Grid Flexibility Needs
AC Level I [established]	110/120 V AC	Opportunity	1.4 to 1.9 kW	8 to 16 hours	
AC Level II [established]	208/240 V AC	Residential	2.8 to 3.8 kW	4 to 8 hours	◔
AC Level II [established]	208/240 V AC	Residential	6 kW	1 to 4 hours	◔
AC Level II [established]	208/240 V AC	Commercial	7 to 19 kW	1 to 4 hours	◐
DC Level I [in development]	200/450 V DC	Commercial	to 36 kW	1 to 2 hours	◕
AC Level III [in development]	208/240 V AC	Commercial	50 to 96 kW	15 to 30 minutes	◕
DC Level II Fast Chargers [in development]	200/450 V DC	Commercial	to 90 kW	15 to 30 minutes	●
DC Level III Fast Chargers [in development]	200/600 V DC	Commercial	to 240 kW	Less than10 min	●

High ● ◕ ◐ ◔ ○ Low

Different EV adoption rates and different levels of EV charging technologies—whether at home or at public charging stations—will pose different, highly localized needs for additional distribution system flexibility. As shown in Exhibit 3-9, nation-wide EV adoption and the related recharging needs could add a total of 8 GWh to 10 GWh of load to the grid system by 2022. Based in part on current hybrid electric vehicle adoption trends, grid-connected EV/PHEV adoption may trend in denser urban/suburban, generally costal, areas of the nation (see Exhibit 3-8). Urban distribution systems may have a particular need for increased grid flexibility to ensure reliability and stability, while working within any existing financial and/or physical grid system considerations.

U.S. EIA EV adoption projections are used as reference data in the following exhibits. However, a number of EV penetration forecasts abound in the public arena. For example a 2011 Electric Power Research Institute (EPRI) has forecasted low, medium, and high EV adoption scenarios in the U.S ranging from 600,000, 1.2 million, or 2.4 million PHEVs on U.S. by 2015 and 3.1 million, 5.8 million, and 12 million EVs in the U.S. by 2020.[xiv]

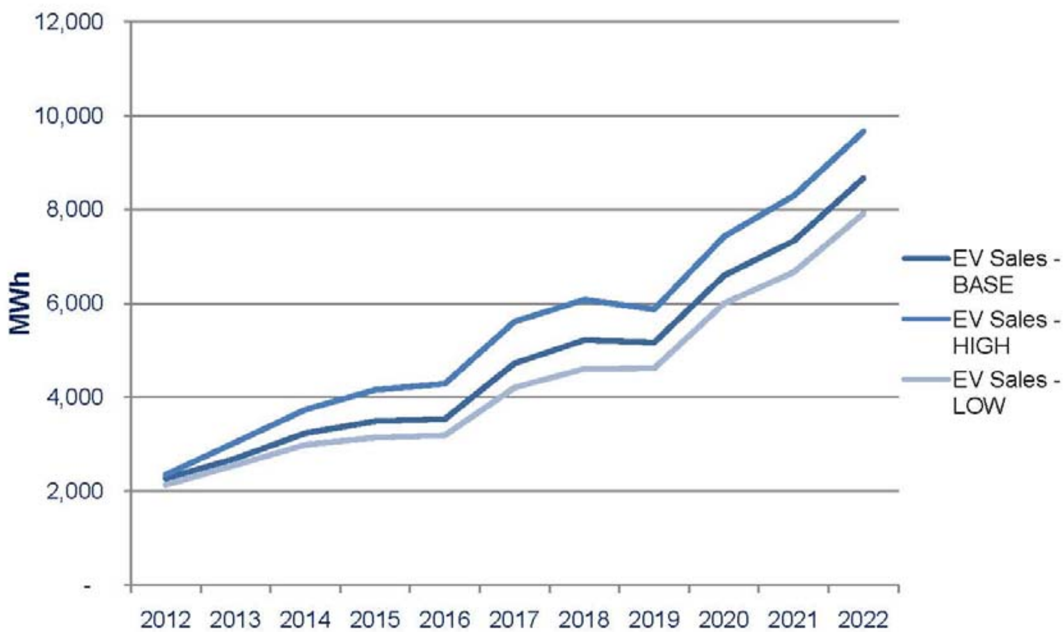
Exhibit 3-8: Forecasted U.S. EV Adoption Distribution & Annual EV Sales 2012-2022



Source: ISO/RTO Council, KEMA

Source: U.S. EIA Annual Energy Outlook 2011

Exhibit 3-9: Annual U.S. EV Adoption Distribution System Load Additions: 2012-2022 (Base, High & Low Scenarios)[3]



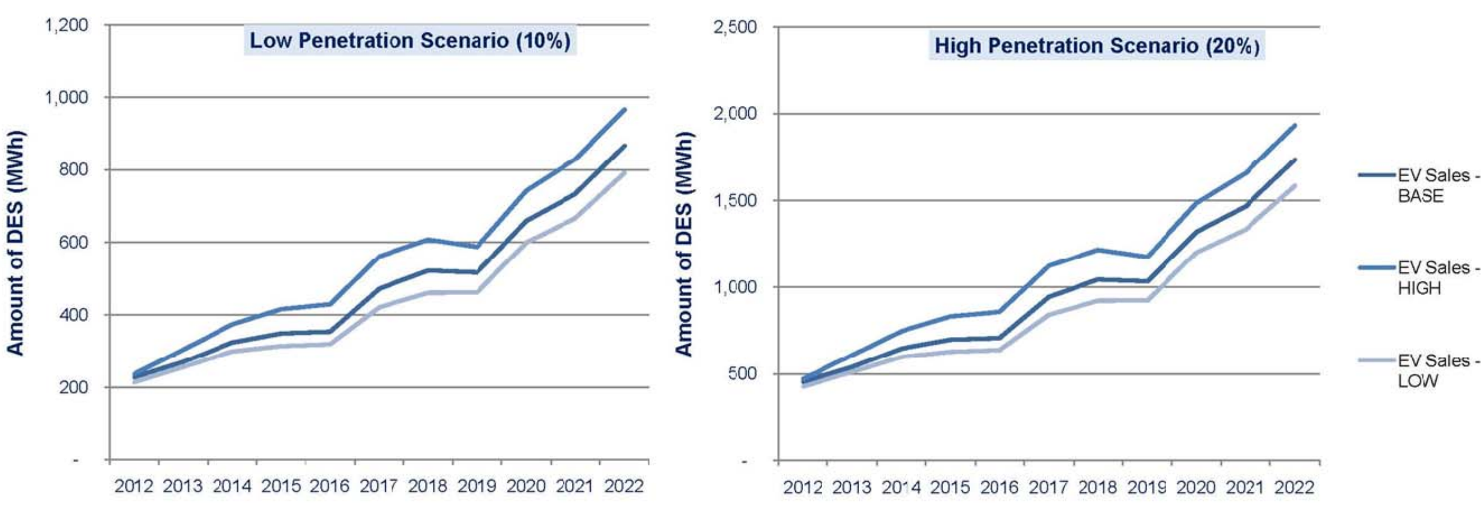
Data Source: U.S. EIA

[3]Based on U.S. EIA EV& PHEV sales projections (cars, light trucks); assumes a 33 kWh average on-board battery capacity, battery capacity assumed to increase from 20 kWh to 40-50 kWh over next 10 years.

The specific grid system flexibility needs of EV integration are difficult to predict due to the localized variables in adoption, technology developments, and use/driving patterns influencing current and future EV adoption. However, for the first ten years, the considerations for local distribution systems management are expected to be at the feeder level.

In the early market development phase, EV adoption may tend to “cluster” in specific locations versus even distribution across the grid system. DES offers a highly adaptive option to support the flexibility needed at the local distribution transformers that serve the EV customers. The need for additional system flexibility depends on a given transformer’s size, loading, and ability to absorb heat. As a scalable and even mobile solution, DES offers a flexible means to meet the unfolding needs of EVs and can help make wide-scale consumer adoption of EVs a reality. Local distribution system flexibility considerations to support EV adoption would need to be assessed on a system-by-system basis. However, assuming 10-20 percent of the nation’s distribution transformers could need a greater degree of flexibility, installing upward of 800 MWh to 2,000 MWh (0.8 GWh to 2 GWh) of DES by 2022 could help meet the grid system needs of EV integration (see Exhibit 3-10).

Exhibit 3-10: Annual Amounts of U.S. DES to Help Ensure Grid Flexibility to Support Forecasted EV Adoption: 2012-2022 (Base, High & Low Scenarios)[4]



[4]Based on U.S. EIA EV& PHEV sales projections (cars, light trucks); assumes a 33 kWh average on-board battery capacity and DES supporting 10-20% of new EV load added to nation’s distribution transformers

3.2.2 DES and EV Affordability

Perhaps the single greatest current barrier to widespread adoption of EVs is the cost of EVs relative to vehicles powered by traditional internal combustion engines. The cost of EVs involves a range of interrelated, and often complex, considerations and ultimately requires fundamental advancements in technologies to address. Advanced batteries represent a significant portion of EV cost, typically between 30-50 percent of total cost, and account entirely for the difference in price between EV's and traditional automobiles—excluding the battery, EVs are in fact simpler and cheaper to build than traditional automobiles. Trends in battery production and costs will influence trends in EV adoption. DES helps lower the cost of EV batteries by (1) contributing to economies of scale in the production of advanced batteries, and (2) offering an opportunity for second-life revenue stream for EV batteries, enabling manufacturers to subtract the value from EV "sticker prices."

Exhibit 3-11 highlights current EV battery costs versus target level prices needed to make EVs more affordable and support wide-scale EV adoption. Sixty-five percent of Americans are unwilling to pay more than for an EV than the price of a gasoline car.[xv] Until and unless battery costs come down, wide-scale EV adoption will remain an elusive target to achieve.

Exhibit 3-11: EV Battery Costs: Current vs. Future for Competitive Positioning & Consumer Affordability

EV Battery Cost Only (lithium ion)	$/per kWh	Total Battery Cost ($)
Current – High[1]	$1,375 - $1,500	$33,000 - $36,000
Current – Mid[2]	$800 - $1,000	$19,200 - $24,000
Current – Low[3]	$750 - $800	$18,000 - $19,200
Forecasted – 2013[1]	$670	$16,000
Forecasted – 2015[1]	$420	$10,000
Forecasted – 2020[2,4]	$250-$350	$6,000-$8,400
Target to be Competitive[5]	$200	$4,800
% reduction in current cost for consumer affordability	**75% - 85%**	

* Assumes: 24 kWh required capacity for 100-mile range EV (small sedan) [xvi]

1. Administration's Blueprint for a Secure Energy Future
2. Bloomberg New Energy Finance
3. J.D. Power & Associates
4. Deutsche Bank
5. Automotive industry analyst estimates

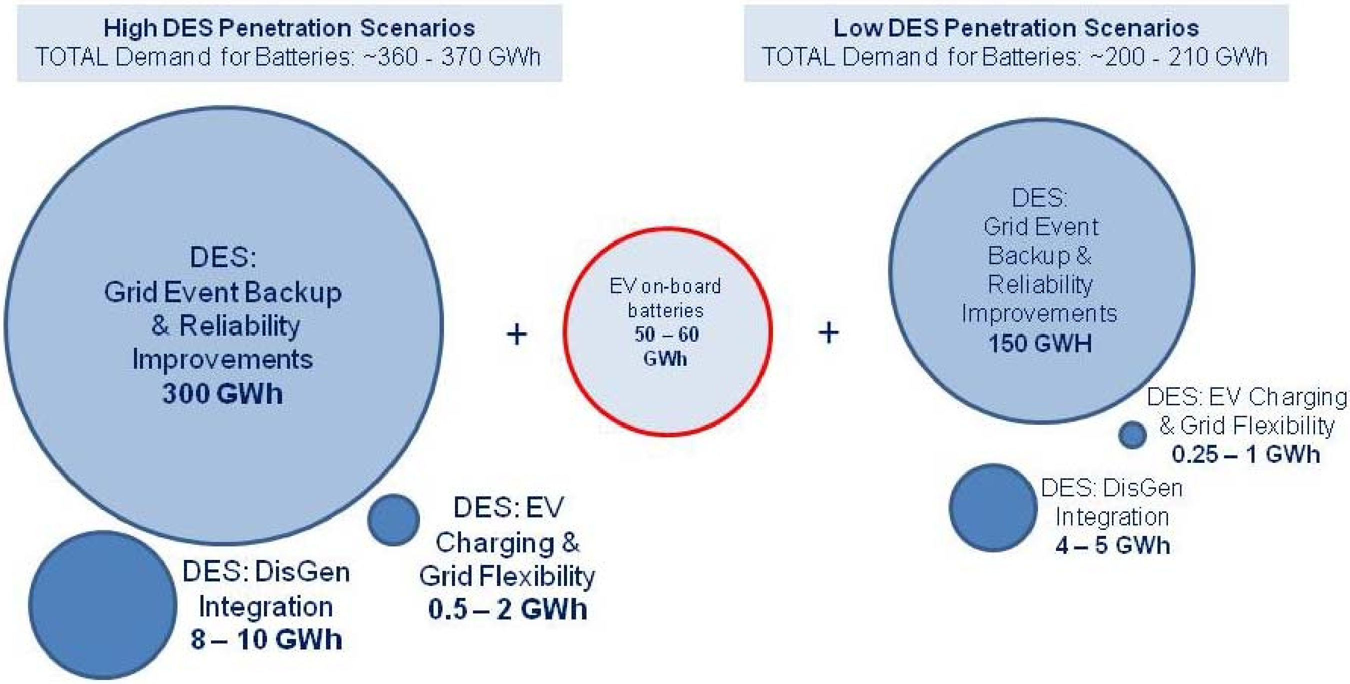
The core cost driver of EV batteries is the cell-level materials. Addressing this cost component requires work around cell chemistries and around reducing the amount of materials required at the cell level before manufacturing the batteries themselves. At the battery level, one of the many avenues to reducing the cost of EV batteries is improving the economies of scale of battery manufacturers, permitting manufacturers to amortize fixed plant costs over a larger number of battery units. Greater volume manufacturing can also help manufacturers gain experience in what is still a new technology, and increased manufacturing experience could further help realize additional cost savings.

DES and EVs can use the same types of advanced batteries or, at a minimum, can use battery systems and controls incorporating a high degree of commonality. By aggregating the demand of both the DES and EV markets, battery manufacturers could potentially achieve economies of scale and lower unit production cost far more quickly than if they had to rely on demand from the EV market alone. As a result the price of both EVs and DES systems could fall, helping to support higher rates of consumer adoption of EVs and higher rates of utility deployment of DES systems. As depicted in Exhibit 3-12, the timing and amount of DES implemented on the nation's grid system for grid event backup and reliability improvements (see section 3.1.1), EV charging reliability and renewable distributed generation integration could help influence the extent and speed at which economies of scale for advanced battery technologies is achieved in the U.S.

The technical application synergies between DES and EVs could offer additional EV cost-reduction opportunities for consumers through recycling or "second-life" use of EV batteries. EV batteries have sufficient capacity remaining to add value to utility applications once removed from the vehicle. EV batteries could provide several advantages for grid-based DES systems and applications including:

- Safe public deployment (well established safety standards)
- Expected cost reductions with new chemistries and increasing volumes
- Source of high quality secondary use batteries
- Likely performance development as EV's are a priority in several countries
- Compact sizing
- Reliability over a wide range of operating temperatures
- Ease of recycling

Exhibit 3-12: Achieving Advanced Battery Economies of Scale with DES & EVs[5]



NOTE: Illustrative figure only; not to scale.

If EV batteries are manufactured with DES-based use and/or reuse in mind, the automotive industry can "predict a harvest" and subtract the revenue stream from the EV cost to consumers. For example, by leasing the battery rather than selling it with the vehicle, total vehicle costs to consumers could be decreased.

A June 2011 Oak Ridge National Laboratory (ORNL) economic analysis of deploying used batteries in power systems found area regulation, T&D upgrade deferral, and electric service power quality to have the most attractive value proposition for secondary use of EV batteries.[xvii] Additional in-depth analysis and initial deployment of used EV batteries as they become available is needed to better understand the potential second life value proposition. The ORNL

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[5]NOTE: Chart is based on data available in the public domain to provide a general sense of the advanced battery market scale with ranges of DES implementation in addition to demand for on-board EV systems. In-depth market penetration modeling and analysis is beyond the scope of this paper. A single DES unit may be able to support multiple applications, which would consolidate a portion of the demand associated with DES applications.

EV on-board battery GWh range is based on U.S. EIA EV adoption forecasts and assumes a 33 kWh average on-board battery capacity.

report also noted that the identified application areas are not likely to offer the market scale needed to utilize the full volume of secondary-use EV batteries predicted for 2020 and beyond.

The battery lease model and secondary use of EV batteries in DES remains an open question. A significant portion of EV battery cost is in vehicle system integration, controls and management versus battery cells. As such, the potential benefit to EV consumers needs further assessment. Likewise, developing an aftermarket for EV batteries depends on several factors, including validating remaining useful life claims and suitability for grid applications. The ORNL June 2011 report notes that secondary use grid application cost is a key determining factor. The grid-application cost depends not only on the cost of the used batteries themselves, but also on costs associated with balance of system, refurbishment, transportation, and operation and maintenance (O&M).

There is not yet a market to value EV batteries separately. However, there could be such a market in the near future with cross-industry collaboration under way. For example, the previously cited ORNL June 2011[6] study explores the various possible markets for secondary use of EV lithium ion batteries and the cost-competitiveness of these batteries for DES system applications. General Motors and ABB are also looking at ways to reuse Chevrolet Volt batteries and how this reuse plays into reducing cost of EVs.

4. Barriers to Commercial Deployment of DES Systems

As summarized in Exhibit 4-1, deploying DES systems in electricity distribution systems around the country holds promise to help advance the nation's near- and longer-term national energy goals and serve the national interest by:

- Stabilizing the national security grid and protecting it against natural and man-made disruptions
- Enabling the grid integration of variable renewable and distributed electricity generation required or targeted by 38 states and three independent power authorities, and

[6] ORNL/TM-2011/151, "Economic Analysis of Deploying Used Batteries in Power Systems," June 2011.

- Support efforts to make electric vehicles more affordable and convenient for consumers to use and supporting national energy independence.

Exhibit 4-1: The Role of DES in Serving the National Interest

National Energy Policy Objective	National Interest	Role of DES in Serving the National Interest
1. Electric grid system reliability & stability	Protecting national grid security by reducing the vulnerability of local distribution systems to disruption from natural & malicious causes	• Supporting reliable grid operations through ancillary services including area regulation & voltage support • Helping reduce frequency & duration of grid events • Backup power source during grid events • Enabling T&D upgrade deferral – address challenges to urban & rural distribution system upgrades • Supporting consumer energy cost management such as time of use & demand charge management
2. Renewable distributed generation portfolio	Enabling achievement of state renewable energy goals by protecting the stability of the national grid	• Integrating renewable variable energy resources and distributed generation • Reduce output volatility, improve power quality • Firming intermittent renewable capacity • Matching supply availability to demand peak load • Backup for unexpected generation shortfall
3. Mass consumer adoption of EVs	Supporting national energy independence by helping to make EVs more affordable	• Ensuring grid flexibility to support EVs and charging infrastructure • Ensuring reliable, stable and available electricity supply for consumer charging needs • Supporting economies of scale in advanced battery production to reduce EV costs for consumers costs

Yet despite these benefits of DES deployment, actual installation of DES systems has been slow and largely limited to government-funded demonstration projects. Four principal factors account for the slow pace of DES deployment and are barriers to our nation's ability to capitalize on the benefits of DES technology.

4.1 Technology Standardization and Operating Experience

Although DES systems can be owned and operated by electricity end-users (e.g., residential energy storage systems) and by third-party service providers (e.g., demand aggregators), because DES technology primarily impacts regulated electricity distribution systems, it is likely that the large majority of deployed DES systems will be owned and operated by regulated electric utilities. By design, regulated electric utilities are cost sensitive and place a high premium on system reliability. Accordingly, technological conservatism is the rule rather than the exception among regulated utilities, which require extensive validation and testing of any new technology before deploying it on a distribution system.

DES technology is by any measure a new technology and a new innovation in electric power. Local storage of electricity has been made possible by relatively recent advances in electrochemical energy storage, power electronics, communications, and systems software. Combined, these advances enable separate, individual energy storage devices to be operated as a single network.

The relative novelty of DES technology poses two problems for regulated utilities. First, because the technology is new, utilities have not had opportunity to test it in operational settings. While DES systems may be well designed and offer multiple benefits to system operators, those benefits will remain largely theoretical until such time as utilities gain sufficient experience with those systems to feel comfortable with putting them into widespread service.

The second issue is one of cost. Although DES systems are small in relation to large-scale centralized energy storage systems and other power infrastructure, their deployment in multiple locations throughout a distribution system poses an obvious cost challenge. Key to the economic success of DES systems is the development of standardized, “plug-and-play” system configurations that can be easily manufactured and installed by utility crews with little specialized training. This standardization does not require the development of new technology; the technology already exists. But it does require that the utility industry settle on a very limited number of specific design specifications for a limited number of DES applications. This vetting of designs and resulting standardization will naturally occur as utilities gain experience with DES systems and share their experience with other utilities.

4.2 Regulatory Barriers to Capturing Multiple Value Streams

As outlined in Section 2.2, one of the benefits of DES systems is their ability to provide a number of different services to the grid. In theory, the owner of a DES system that provides back-up power to residential end users, frequency regulation to an ISO, and power balancing to a renewable energy generator should be able to be compensated for each of those services. The reality, however, is more complicated.

Because the system of regulating the grid and setting rates for different grid services substantially predates the development of the technological ability of an asset located on a distribution system to affect and benefit other assets located throughout the grid, it is often not possible for a DES system operator to be compensated for all of the values that the DES system provides. State regulators, which may have jurisdiction over assets located in the electricity distribution system located in that state, have no power to regulate or set rates for a wind power generator in a neighboring state that might require power balancing or an ISO that may be looking for frequency regulation services. The FERC may have jurisdiction over ISO's and the frequency regulation market, but it has no jurisdiction over distribution assets or over who pays for back-up services rendered to commercial and residential electricity end-users.

The result is that no clear regulatory procedure exists through which DES system operators can apply to be compensated for all of the benefits that their systems can potentially provide. This is a serious barrier to DES system because if DES systems can only be compensated for providing one function (or a limited number of functions) on the grid, it is unlikely that they will appear to be economic investments to any utility or utility regulator.

4.3 Inability to Monetize the National Value of DES Systems

Exhibit 2-2 outlines many of the services that DES systems can provide on the grid. Several prior studies of storage technology (e.g., EPRI*, Electricity Energy Storage Technology Options, A White Paper Primer on Applications, Costs, and Benefits*, December 2010; Southern California Edison, Moving Energy Storage from Concept to Reality, 2011; Sandia National Laboratories, *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide*, SAND2010-0815, February 2010) have not only identified those services but tried to assign monetary values to them. As explained in Section 4.2, permitting DES system owners the regulatory ability to aggregate and be compensated for these services would be a key enabler of DES technology.

But in addition to the widely recognized benefits of storage recognized in prior studies, there are three national benefits of DES systems that have received little more than indirect attention. The value of these benefits does not figure into the monetary benefits of storage assigned by earlier studies. More importantly, the value of these national benefits cannot factor into the value calculation of any local utility regulator because these values are captured, not by local ratepayers, but by the nation as a whole. The three national values of DES technology are:

- Supporting national energy independence by making electric vehicles more affordable (*see* Section 3.1)
- Protecting the security of the national grid by reducing the vulnerability of local distribution systems to disruption from natural and malicious causes (*see* Section 3.2.1), and

- Enabling the achievement of state renewable energy goals by protecting the stability of the national grid (*see* Section 3.2.2).

The principal barrier to widespread deployment of DES systems is the inability of local electric ratepayers asked to pay for DES systems to recover any monetary benefit for the national values that the DES systems they pay for will achieve, even though everyone recognizes those benefits. The inability of local ratepayers to be compensated for the common national benefits of DES technology has consigned this promising technology to near obscurity.

4.4 Cost of DES Interconnection

For DES to effectively function as a larger unit – and thereby offering grid system benefits locally as well as upstream at the transmission and generation levels – the individual DES units need to be controlled and dispatched in an aggregated manner. It is this aggregation that enables the desirable flexibility DES brings to a modernizing grid system. This useful flexibility does come with a cost. While the software component of aggregation schemes is not necessarily more expensive than alternative control schemes that need to be developed, the hardware for this communication and control could be higher, at least at the beginning when they are not yet quite standardized. However, due to their potential to be turned into commodity items like distribution transformers, this cost is expected to come down as deployment of DES expands.

5. Recommendations to Advance U.S. DES

Advancing the wide-scale adoption of DES advances our national energy policy objectives for a more reliable, diverse and secure energy future. Yet there is much that needs to be done to realize the promise of DES. We believe that continued collaboration among government and industry stakeholders is the key to further future success. NAATBatt makes the following four recommendations to advance wide-scale implementation of DES needed in the U.S. to achieve national energy policy objectives:

1) **Establish A Coordinated Program of Small, Fast-to-Implement Demonstration Projects Among Geographically Diverse Electric Utilities to Validate DES Applications and Identify Optimal DES System Configurations.** A series of demonstration projects coordinated among a range of electric utility companies around the country will help utility companies become more familiar and more comfortable with DES systems and mitigate new technology risk. The demonstration projects will help

identify optimal system configurations for certain types of DES systems that can be mass produced and installed on a "plug-and-play" basis.

The white paper working group believes that an important aspect of the demonstration projects advocated by this white paper is that they be smaller and geared to a more urgent time table than most of the DES demonstration projects funded by the U.S. DOE to date. Ideally, projects should be designed to report results within 12 months following construction, and construction should take place on an accelerated schedule following the award of a grant. The working group believes that "fast-tracking" demonstration projects is key to commercializing DES technology.

The white paper working group recommends that the DOE design a program of demonstration projects touching on specific aspects of DES technology and solicit utility companies around the country to participate in individual projects. The assigned projects should be coordinated with projects assigned to other utilities and the results shared. Among the types of projects that the DOE should consider are as follows:

DES Technology Validation

- Duty cycle definition
- Life-cycle testing
- Integration protocols – SCADA, battery MBS function
- Factory & System Acceptance Testing (FAT/SAT) per application
- EV testing

DES Application Validation

- "Bundling" multiple DES Application Benefits
- Combined DES-solar PV Systems
- Interconnection for the aggregation and operation of multiple DES systems
- Impact of high penetration of EVs on the distribution system
- Impact of high-penetration of variable distributed generation (wind, PV) on the distribution system
- Assess the DES value proposition
- Quantify electrical power system performance improvement
- Quantify energy efficiency savings and oil savings

2) **Compensate Local Ratepayers for the National Value of the DES Systems in Which They Invest.** As indicated in Section 4.3, the principal barrier to DES system deployment is the inability of the ratepayers who must pay for DES investments to be compensated for the national benefit of those systems.

The white paper working group recommends that the federal government design a mechanism by which a monetary value can be assigned to capture the national benefits created by DES system deployments. One means of allocating this benefit is through the provision of a tax credit for utilities deploying DES technology that is translated into tangible financial benefit for the utility's ratepayers. The white paper working group believes that tax credits and portfolio standard mandates, while helpful, are not necessarily the most effective means to achieve this benefit recognition. Instead, we recommend providing eligible ratepayers with a simple tangible benefit, such as a credit on a utility bill shown as a benefit that ratepayers can understand and appreciate.

3) **Establish a Coordinated Nation-Wide Approach to DES Regulatory Treatment & Interconnection**. A clear and consistent national framework for energy storage regulatory treatment is need to help guide further developments of policies, market rules, and regulations supportive of wide-scale implementation of DES. Combined with a mechanism to monetize DES benefits of national interest, a coordinated approach to DES regulatory treatment can help eliminate the need to set a specific regulatory asset category for energy storage. By avoiding the historically slow and complex process of regulatory change, the nation can further accelerate the time-frame in which DES can be implemented across our grid system. Requirements for interconnection and impact studies need to be standardized. The U.S. Department of Commerce National Institute of Standards and Technology (NIST) is developing energy storage interconnection guidelines as part of its framework and roadmap for smart grid interoperability standards. In addition, IEEE 1547.7 and IEEE 1547.8 are attempting to address these issues but are slow to be developed and then lack regulatory power to cause utility to comply.

4) **Coordinate with Existing Energy Storage Standards Development Process & Help Inform Standardization of Battery Testing for Grid Applications.** The development of national standards for energy storage technologies and applications is an important part of accelerating the wide-scale implementation of advanced battery-based DES in the U.S. Ultimately standards can help facilitate a comparison of DES systems across specific applications, help standardize DES solutions, and help lower the costs of DES.

   Numerous energy storage standards development efforts are underway by organizations that have been serving the electric utility industry for years, such as IEEE. Federal agency involvement in the process can help support these on-going efforts, continuing to work in collaboration with existing standards development organizations and industry groups already addressing this critical issue.

As battery DES technology continues to advance, some standardization around benchmark materials and around application-specific testing conditions will be needed over the next 10 to 15 years. Standardization of DES devices will help to reduce cost and speed the rate of implementation, including standards for:

- Acceptance test plans (electrical, physical, environmental, interfaces)
- Handling momentary overload (inrush) for motor starting
- Overhead (pole-mounted) version
- Communications with the utility (CES hub) and the end customer (home area network interface)
- Functions of the battery based on communications from the utility or the customer
- Communication and security
- Mitigation or avoidance of power quality issues.

In establishing energy storage standards it is critical to take into consideration the maturity of the DES technology as well as the nuances in DES applications on the distribution, transmission and generation levels to ensure a coordinated approach to standards across the spectrum of applications.

5) **Continue to Fund Research, Development and Deployment (RD&D) to Reduce DES Costs**. RD&D initiatives should continue to focus innovations in materials and manufacturing to lower the costs of all components in a DES, including, but not limited to power electronics, packaging, thermal management, SCADA, protection devices (relays), control software, and communications.

6) **Implement a National Outreach Campaign to Educate Stakeholders on the Benefits of DES**. While DES systems are highly complex, many of their benefits are simple and easily understood by the ratepayers, whose support and understanding will be needed for widespread investment in the technology. Educating consumers about the ability of DES systems to provide back-up power during outages and to integrate more renewable energy onto the grid will be important in building support for the technology both among utilities and utility regulators.

The U.S. electricity grid desperately needs to be updated and modernized. Efforts to interest the general public in smart grid technology and to gain support for necessary electric infrastructure investment have largely failed on account of the inability of smart grid advocates to explain to consumers “what is in it for them.” DES technology suffers from no such disability. Supporting national energy independence and protecting grid reliability are widely understood and widely supported public goals. Educating the public about DES technology and its ability to achieve those goals is important and may prove the most effective way to build public support, not such for DES systems, but for the wide range of upgrades to the national electricity grid needed to keep our country competitive in the 21st Century.

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